Drag prediction of rough-wall turbulent flows via data-driven methods

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The uncertainty of drag estimation over rough surfaces in wall-bounded turbulent flows has been a long-lasting flow problem. It is of great interest to the industry, such as the manufacture and maintenance of ship, wind turbine and aircraft etc. Roughness increases the momentum transfer near the wall and the hydrodynamic drag on the wall. The challenge lies in the massive topographic features dependent on the roughness, which may potentially be investigated by data-driven methods. Previous attempts[1,2] on predicting the drag given the statistical parameters by multi-layer perceptron(MLP) with a small dataset. As no general model currently can accurately predict drag over various roughness, we thus further explore the performance of different models on drag prediction with more and diverse roughness dataset, illustrated in Fig 1. The performance is evaluated by the prediction error of drag penalty ΔU^+, which SVR is found to be sufficient given the current dataset. Besides, 'ranking' the rough surfaces based on ΔU^+ is another aspect to assess the model, which can be more critical than drag value estimation. This talk will also explain the significance of non-linearity from either the input or the model when the topographical statistics are used as input features. Additionally, we found that CNN outperforms at learning the spatial correlation between the height and drag, given that the whole spatial height information is preserved which MLP and regression methods can not construct.

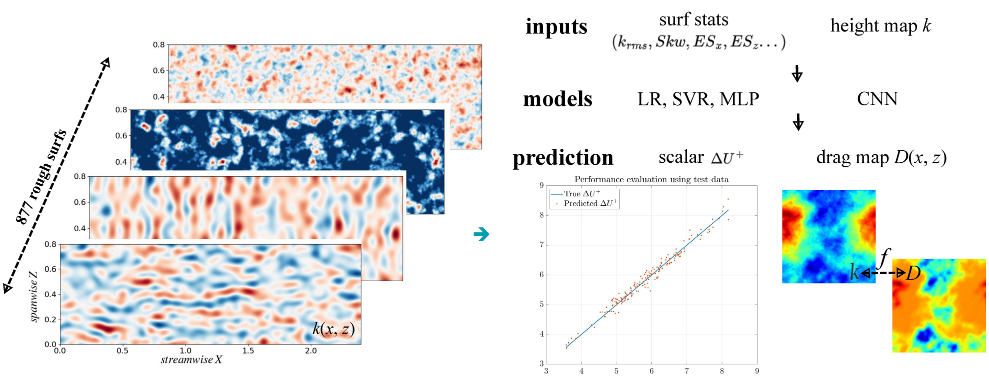

Figure 1: Left panel: four roughness types. Right panel: workflow of different models, i.e. linear regression(LR), support vector regression(SVR), MLP and convolutional neural network(CNN). The inputs are topographical statistics or height map. The output is either the mean velocity loss to a smooth surface, i.e. ΔU^+ or the corresponding drag map D.

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[2]Jouybari et al., *J. Fluid Mech.* **912**, A8 (2006).